Modeling Bimodal Wind-Wave Propagation Resonance

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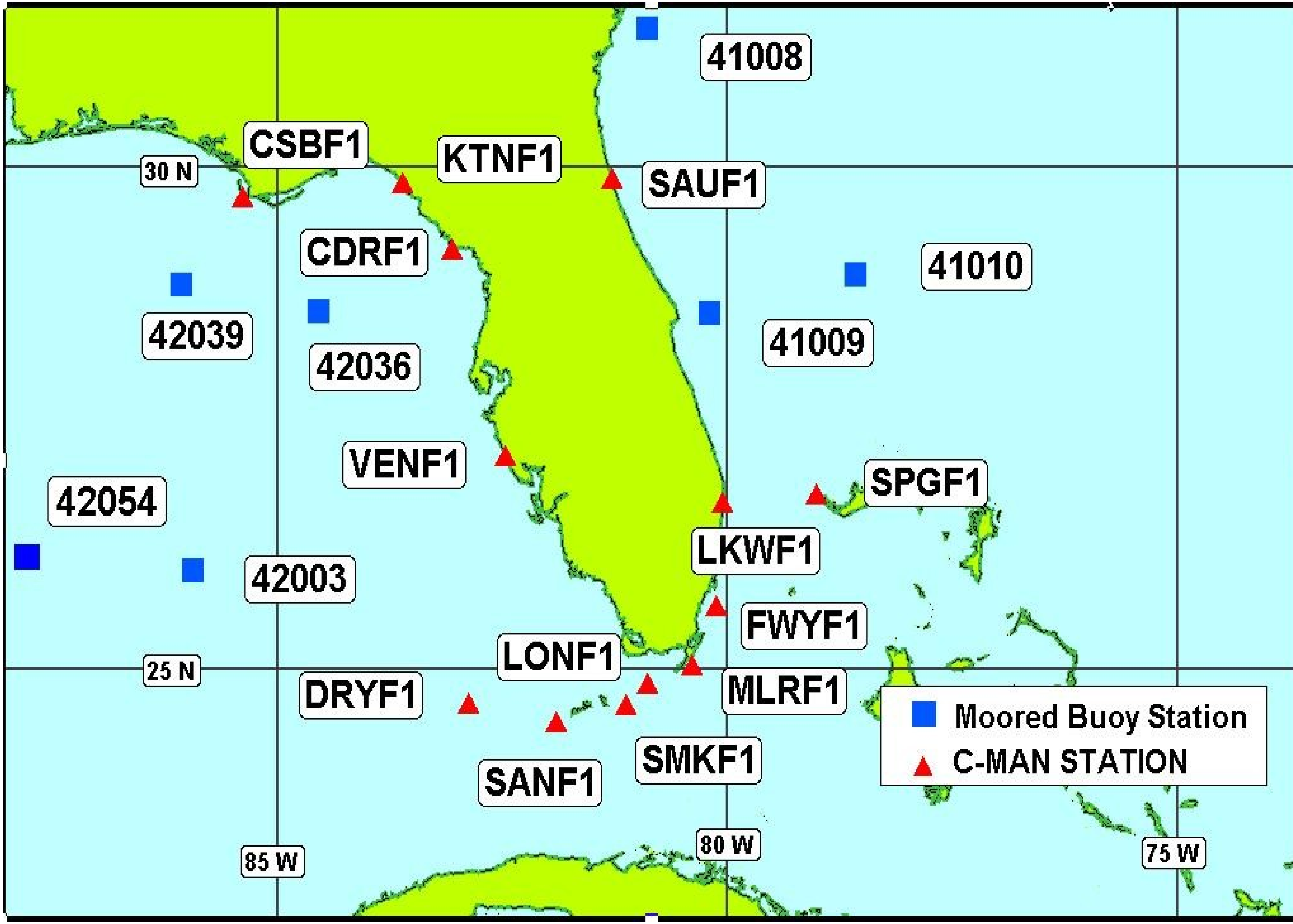
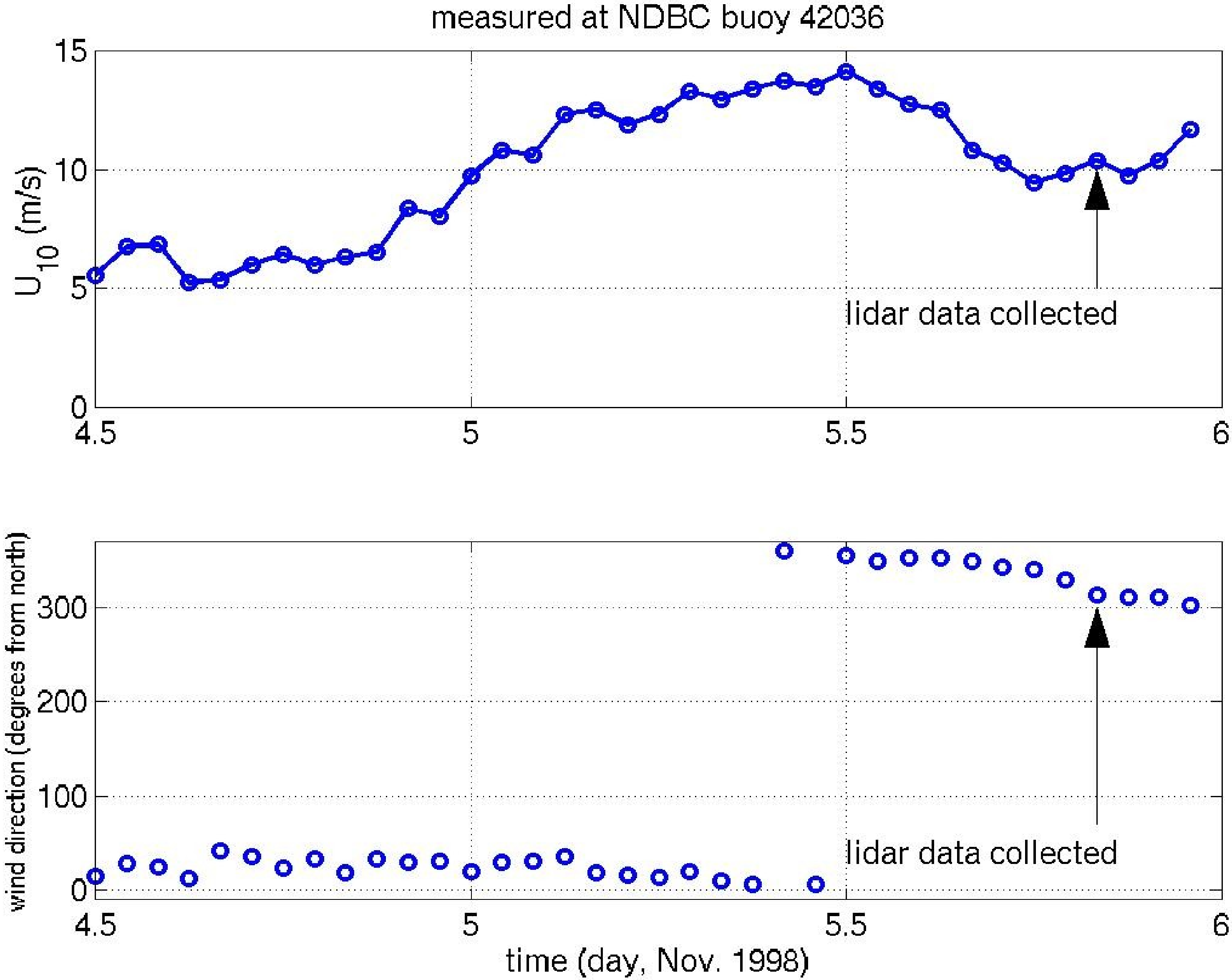
Data set

- Gulf of Mexico
- Nov. 5 1998
- offshore winds
- light southerly swell
- two active wind sea peaks…why?

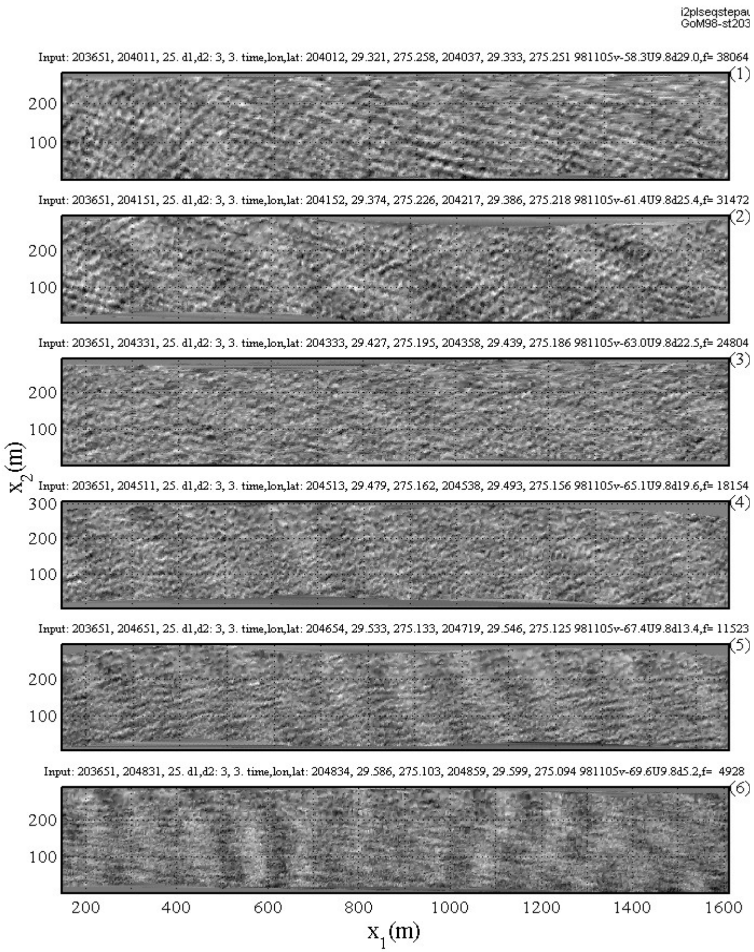


NDBC’s instrument map



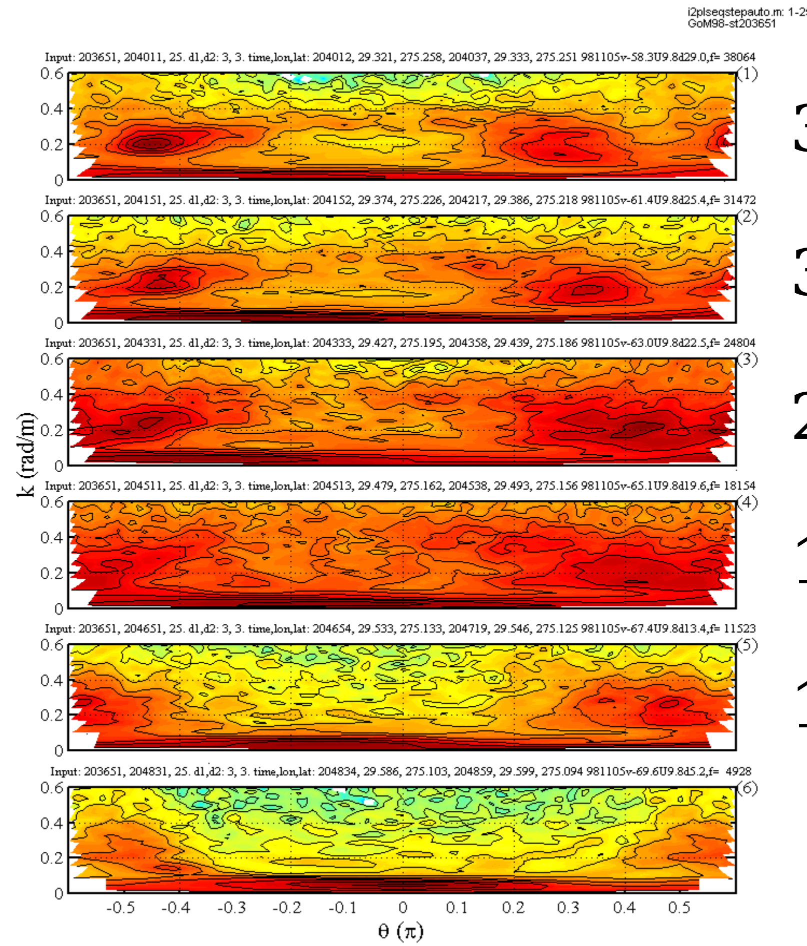
Wind conditions

topography



wind direction

directional spectra



38km

31km

25km

18km

12km

5km

Wind: @θ=0

Propagation resonance

- Philips (1957) propagation resonance condition
- Resonance satisfied where speed of wave crest, al $\theta_r = \pm\cos^{-1}(C_p / U_r)$ the speed of wind

- Purpose: to reproduce behavior observed in data by implementing this resonance condition in a wind-wave model (SWAN)

How to include this in the model?

- We replace the unimodal wind input term with a bimodal term.

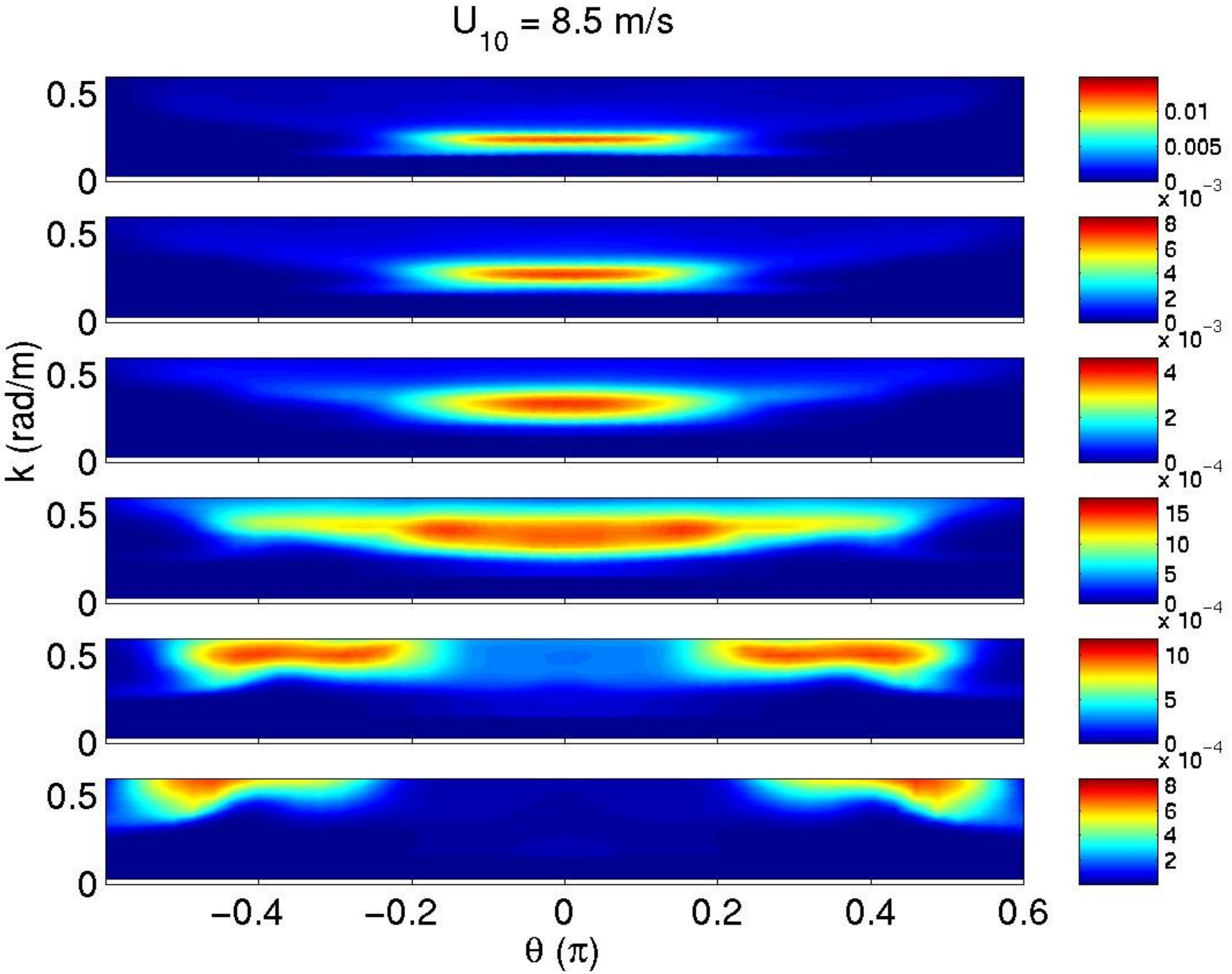
$$B = \max\left(0, 0.25\frac{\rho_a}{\rho_w}\left(28\beta\frac{U_*}{C}\cos\left(\theta_{wv} - (\theta_{wd} + \theta_r)\right) - 1\right)\right)\sigma$$

$$+ \max\left(0, 0.25\frac{\rho_a}{\rho_w}\left(28\beta\frac{U_*}{C}\cos\left(\theta_{wv} - (\theta_{wd} - \theta_r)\right) - 1\right)\right)\sigma$$

We use exponential growth term.
(though Phillips theory is relevant to the linear growth term, not the exponential growth term.)

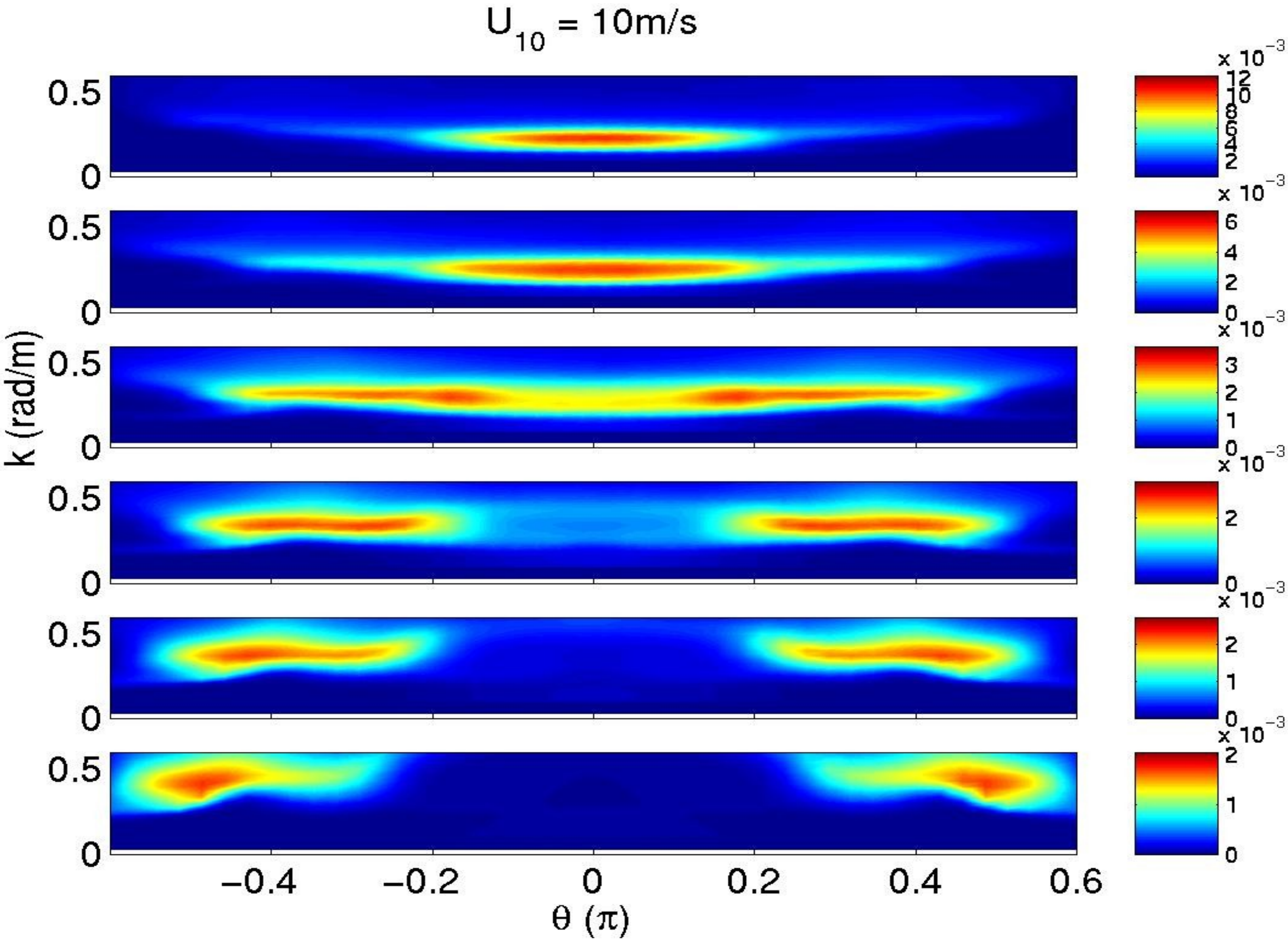
Approach

We attempt to reproduce what is observed in the data using a range of wind speeds (this is essentially the same as re-tuning β in S_{in})

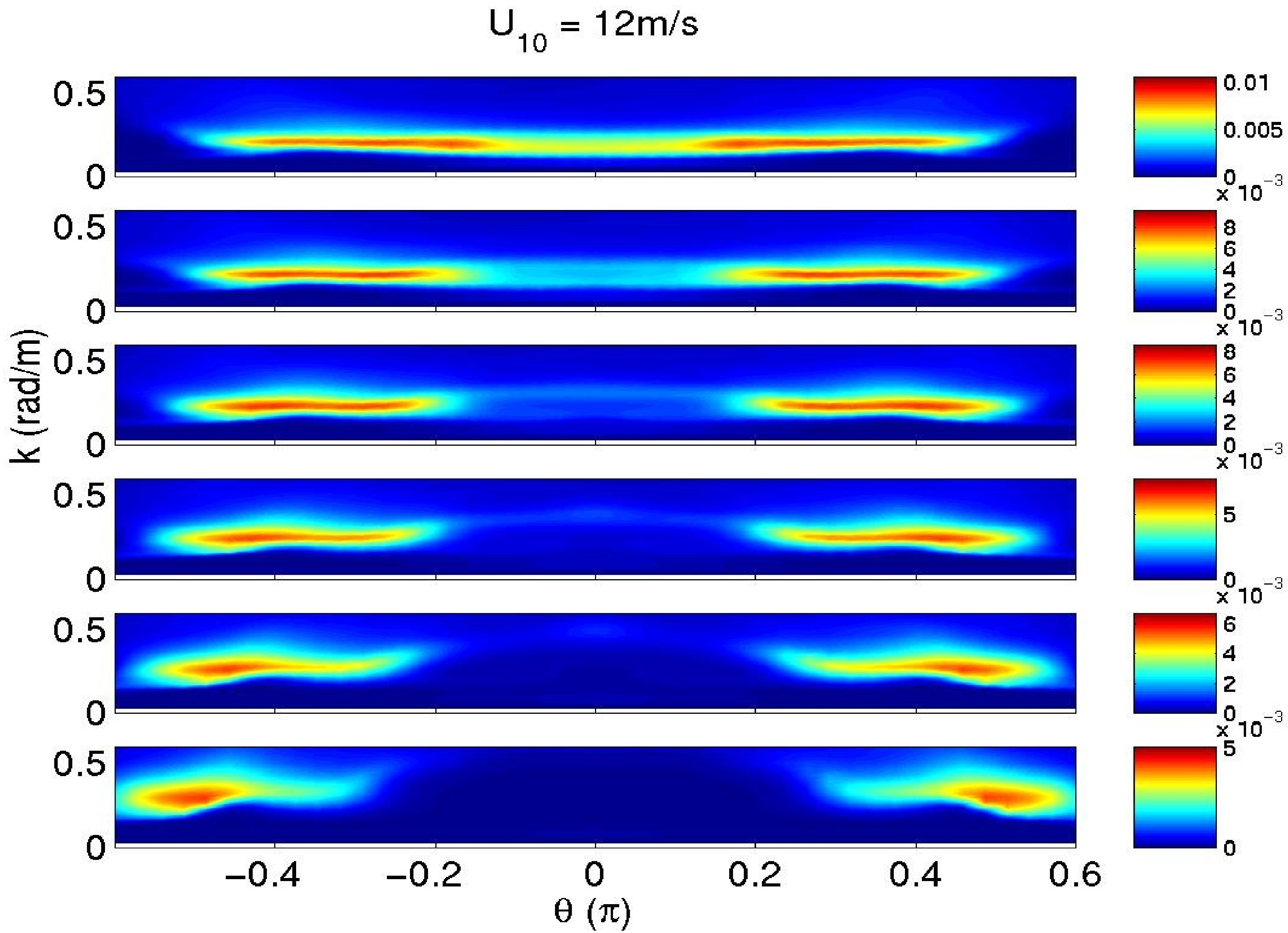


U10 = 8.5 m/s
k (rad/m)
θ (π)
0.5
0
−0.4
−0.2
0
0.2
0.4
0.6
0.01
0.005
x 10−3
8
6
4
2
x 10−3
4
2
x 10−4
15
10
5
x 10−4
10
5
x 10−4
8
6
4
2

SWAN output



SWAN
output



SWAN output

Wave parameters at 38km fetch

source	T_{peak} (sec)	H_{m0} (m)	θ_{peak} (degrees from wind direction)
Lidar data (measured U_{10}~10 m/s)	4.5-5.2	0.9	-80, +50
Original model, U_{10}=10 m/s	4.1	1.1	0
modified model, U_{10}=8.5 m/s	4.1	1.2	±25
modified model, U_{10}=10 m/s	4.3	1.3	±40
modified model, U_{10}=12 m/s	4.4	1.5	±55

Nonlinear interactions?

One--generally accepted--cause of bimodality is nonlinear interactions.

However, this will typically create bimodality at frequencies above and below rather than *at* the peak.

Summary/Discussion

- We feel that this resonance mechanism is the most likely cause of the bimodality observed in the dominant waves.
- Implementation of this modification in a general model would require significant retuning and validation.